FUEL PROCESSORS FOR SMALL-SCALE STATIONARY PEMFC SYSTEMS

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Fuel processors are generally required for proton-exchange-membrane fuel cell (PEMFC) systems that are intended for operation using conventional fuels rather than stored (i.e., compressed, absorbed, adsorbed, or liquified) hydrogen. At Northwest Power Systems (NPS) we are engaged in the development of a multi-fuel capable fuel processor designed specifically for the production of high-purity hydrogen from a wide range of conventional fuels.

The NPS fuel processor combines the functions of steam reforming, hydrogen purification, and heat generation in a single compact device. Hydrogen purification is accomplished using a patented two-stage purifier. Since the purification process is driven by a pressure gradient, the steam reforming reactions are conducted at elevated pressure—typically between 50 psig and 250 psig. The heat input necessary for vaporizing water to raise steam and promote the endothermic steam-reforming reaction is derived from the combustion of a fuel gas stream. The fuel gas stream may consist of some or all of the impurities (waste gases) rejected by the hydrogen purification module.

The majority of the fuel processor development effort has involved methanol as the fuel. Methanol is an ideal fuel as it is cleanly reformed to hydrogen in high yields. In many cases, the operating costs associated with a methanol fuel processor (and, more importantly, a methanol fuel cell system) will be lower than the operating costs associated with other candidate fuels, including natural gas. However, a single fuel selection cannot meet all potential market opportunities. So we have recently adapted the NPS fuel processor to produce high-purity hydrogen from other conventional fuels, including K1 kerosene, diesel, biodiesel[1], propane, and methane.

In evaluating the performance of the NPS fuel processor using these various fuels, we are interested in three criteria: 1) the product hydrogen purity, 2) the maximum flow rate of product hydrogen, and 3) the energy efficiency of the fuel processor. The first two criteria are self explanatory, but energy efficiency values require further explanation. The typical practice is to calculate energy efficiency as follows:

= (*LHV product hydrogen*)/(*HHV fuel*)

where: *LHV product hydrogen* is the lower heating value of all the product hydrogen, regardless of purity, produced by the fuel processor; and

[1] Northwest Power Systems gratefully acknowledges Jim Kerstetter and the Pacific Northwest and Alaska Bioenergy Program administered by Washington State University, Seattle, for the supply of biodiesel fuel used in this evaluation.

HHV fuel is the higher heating value of fuel fed into the fuel processor.

This calculation of energy efficiency suffers from two shortcomings. First, the product hydrogen is treated as if it only has value as a fuel. Thus, no consideration is given to whether the hydrogen can be entirely consumed by the fuel cell to productively generate useful electrical power. Second, the calculated value provides no reference to the theoretical limit, and so provides no figure of relative merit. For these reasons, we are proposing that efficiency be calculated as the net efficiency according to the following equation:

$$\eta_{net} = (\textit{LHV fuel cell hydrogen})/(\textit{HHV fuel} - \textit{steam reforming heat input})$$

where: *LHV fuel cell hydrogen* is the lower heating value of product hydrogen that can be consumed productively by the fuel cell;

HHV fuel is the higher heating value of fuel fed into the fuel processor; and

steam reforming heat input is the theoretical heat input required to vaporize water to raise steam as well as to satisfy the enthalpy of the steam reforming reactions.

For all fuels tested we find that the product hydrogen purity is exceptional; typically <1 ppm CO, <1 ppm CO_2, with the hydrogen purity exceeding 99.8%. Product hydrogen flow rates are in the range of 20-30 std. L/minute at the present time. We expect to see increases in hydrogen output as further improvements are made to the fuel processor. Net efficiency is good, ranging from about 70% to 90%, and shows little dependence on the choice of fuel. Further details will be presented in the paper.

NPS has intentionally targeted fuel cell applications requiring 10 kW or less electrical output. By demonstrating that our fuel processor is compatible with virtually all commonly available fuels, we can target potential applications without regard to fuel selection. Soon, an automated controller will be available for the fuel processor to further increase its utility in fuel cell systems. Finally, the fact that the fuel processor provides a product hydrogen stream essentially devoid of both CO and CO_2 opens the possibility of coupling the fuel processor to alkaline fuel cells in addition to PEMFCs.